§64. Measurement of Pitch Angle of Magnetic Field Using Motional Stark Effect (MSE) Spectroscopy

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The Motional Stark Effect (MSE) spectroscopy using linear polarizer and spectrometer has been installed in LHD to measure the radial profile of rotational transform. The co-NBI (NBI#2) is injected for 0.3 – 3.3sec, while the ctr-NBI(NBI#1) and probe beam (NBI#3 only one ion source) is injected for 3.3 – 6.3 sec to study the current distribution driven by NBI for the plasma with magnetic axis of 3.6m and magnetic field of 1.5T. The toroiddal current changes its sign from co-direction (Ip>0) to counter-direction (Ip<0) after the injection of ctr-NBI.

Figure 1 shows the spectra of emitted from the neutral beam measured with different polarization angle at t=3.4sec (Ip = 61 kA) and t = 5.9sec (-81kA). The spectra with 0° degree polarizer mainly corresponds to the σ component, which is polarized parallel to the magnetic field, while the spectra with 90° degree polarizer mainly corresponds to the π component. which is perpendicular to the magnetic field. The spectra with 45° and 135° degree polarizer are mixture of σ component and the π component and the differences give the polarization angle. The increase in the ratio of intensity with 45° polarizer to that with 135° polarizer, I(45) to I(135) indicates the change of pitch angle due to the toroidal current. The line boarding of each component is mainly due to the beam divergence.

The polarization angle γ_p is given by

$$\gamma_p = (1/2)\tan^{-1}([I(45)-I(135)]/[I(0)-I(90)])$$

As seen in Fig.2, the polarization angle shows strong wavelength dependence. This is because the Doppler shift and pitch angle changes along the line of sight within the finite beam width due to beam divergence. Since the line of sight is nearly parallel to magnetic field, the change of pitch angle is toroidal variation not the radial variation. The polarization angle becomes more negative associated with the change of toroidal current from positive (co-direction) to negative (ctr-dierction).

Figure 3 shows the radial profiles of polarization angle difference from that in vacuum measured with MSE and calculated with the parabolic current profile $j_0(1-\rho^2)$. The polarization angle in vacuum is derived from the MSE measurements in calibration shot, where the probe beam injected gas target (no plasma). The measured polarization angle agrees with that calculated both for the co- and ctr-toroidal current. In order to estimate the rotational transform, the change of polarization angle in time (from 3.4sec to 4.9sec) measured is compared with that calculated with the three different current density and rotational transform profile. The polarization angle measured is consistent with the polarization angle calculated with the parabolic current density profile, which gives central rotational transform of 0.25.

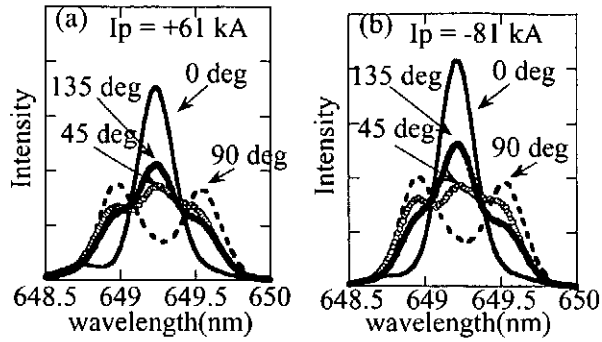

Fig. 1. MSE spectrum at R=4.02m for the plasma with toroidal current I_p of (a)+61kA and (b) -81kA.

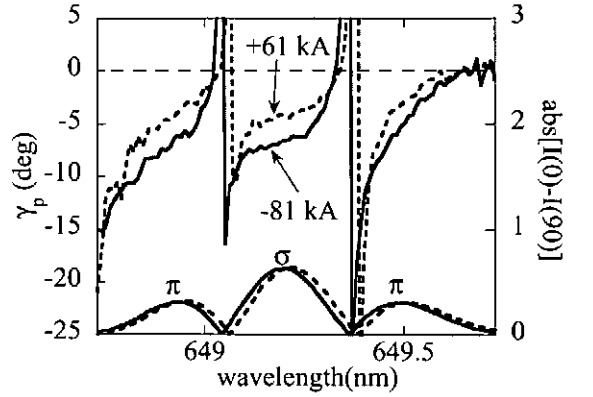

Fig.2. Polarization angle as a function of wavelength at σ and π component for I_p = +61kA and I_p = -81kA.

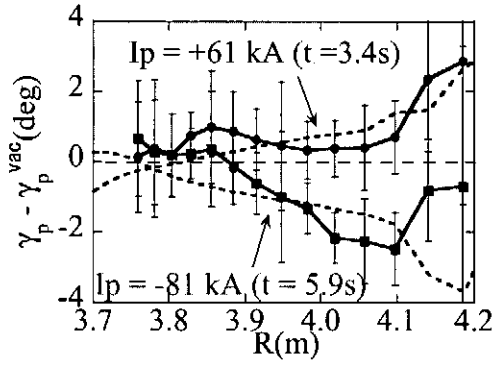

Fig.3. Radial profile of polarization angle measured (closed circles) and calculated (doted lines) for the plasma current of +61 kA and -81 kA.

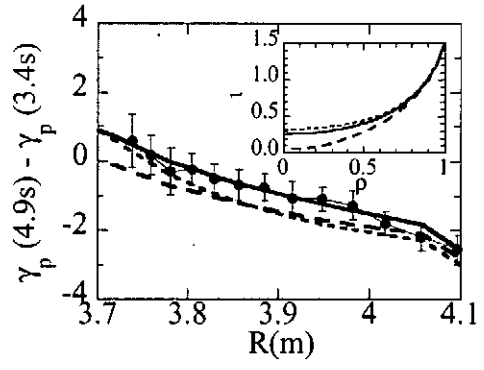

Fig.4 Radial profile of change in polarization angle due to the plasma current and rotational transform with various current distribution; parabolic(solid line), more peaked (dashed line), more broad (dotted line).